The NBL Pool

Background

This problem applies mathematical principles in NASA's human spaceflight.

Human spaceflight is an important part of NASA's mission. From lunar exploration to the completion of the International Space Station (ISS), exploring space has been and continues to be a complex endeavor. Missions that involve human crewmembers require extensive research, precise planning, and preparation.

One critically important mission component involving crewmembers is the spacewalk. To prepare, astronauts train at one of the largest indoor pools in the world—NASA's Neutral Buoyancy Laboratory (NBL), located at the Sonny Carter Training Facility in Houston, Texas. NASA uses the NBL pool not only for astronaut training and the refinement of spacewalk procedures, but also to develop flight procedures and verify hardware compatibility—all of which are necessary to achieve mission success.

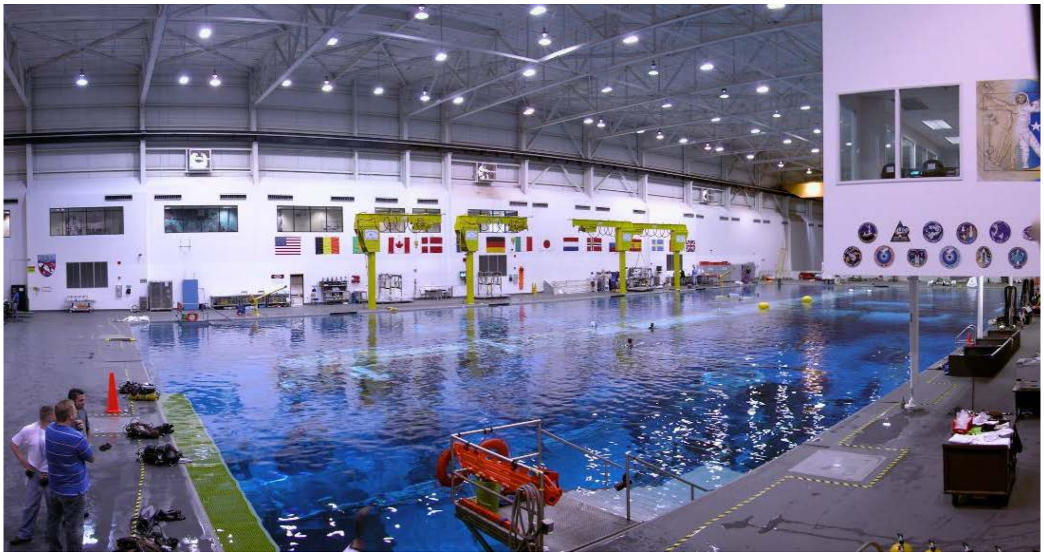


Figure 1: View of entire pool at the Neutral Buoyancy Lab (NBL)

The NBL pool is 62 m (202 ft) long, 31m (102 ft) wide, and 12 m (40 ft) deep. It is sized to perform two suited test activities simultaneously, and it holds more than 23 million liters (6 million gallons) of water. Even at this size, the complete International Space Station (ISS), with dimensions of 106 m (350 ft) by 73 m (240 ft), will not fit inside the NBL pool (see Figure 1).

The water within the NBL pool is recycled every 19.6 hours. It is automatically monitored and controlled to a temperature of 82°–88° Fahrenheit to minimize the potential effects of hypothermia on support divers. It is also chemically treated to control contaminant growth while minimizing the long-term corrosion effect on training mockups and equipment.

The NBL pool enables crewmembers to train properly in a simulated weightless space environment. With the assistance of support divers, astronauts in spacesuits are weighted in the pool to perform simulated extra-vehicular activities (EVA), or spacewalks, on full mockups of parts of the ISS, other spacecraft vehicles, and various payloads.

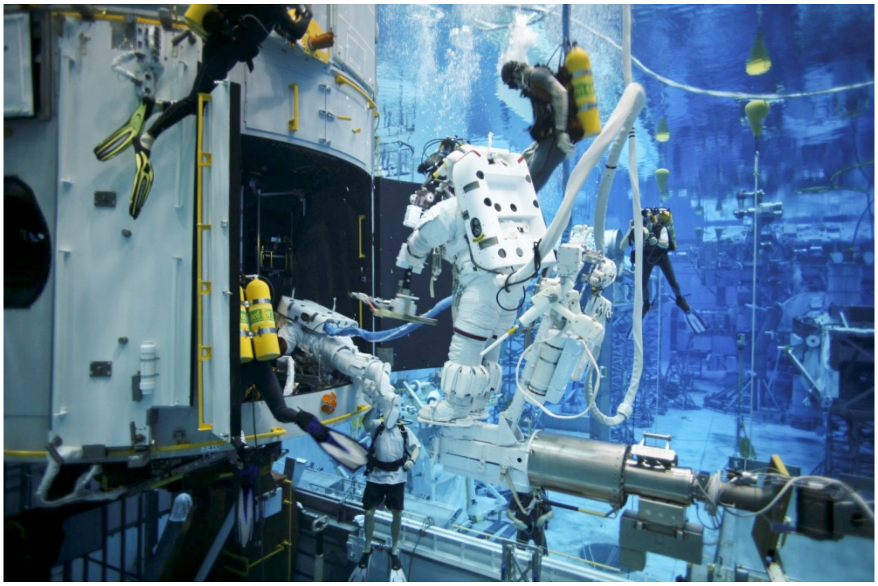


Figure 2: Astronauts practicing for a spacewalk in the NBL

Instructional Objectives

- You will apply formulas for volume of geometric solids, using appropriate units of measure.
- You will solve application problems involving geometric solids.

Directions: Read through the problem set-up and complete the following questions.

Problem

The NBL pool was sized to perform two training activities simultaneously; each using mockups sufficiently large to produce meaningful training content and duration. The pool is 62 m (202 ft) in length, 31 m (102 ft) in width, and 12 m (40 ft) in depth. The actual span of the International Space Station is 110 m by 73 m, and it doesn't fit directly into the pool. But by bending the mockup into what is called the wishbone configuration, it allows as much of it into the pool as possible (see Figure 3).

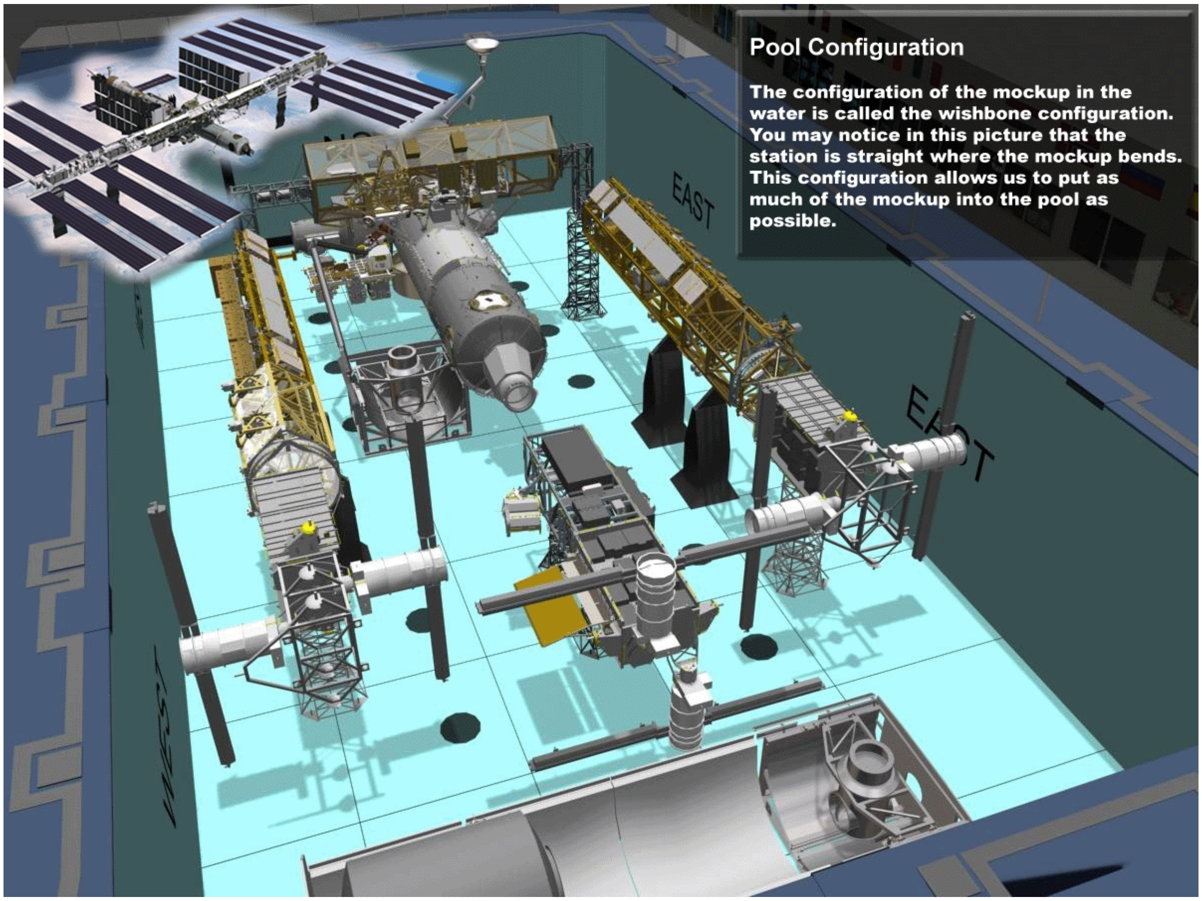


Figure 3: 3-D representation of pool layout

Questions

Figure 3 shows a top view comparison of the NBL pool, an NFL football field (without the end zones), and the ISS.

1. Would the wishbone configuration be necessary if the NBL pool had the same length and width as an NFL football field? Explain your reasoning.

2. How many meters would need to be added to the length and width of the NBL pool to accommodate the entire ISS without using the wishbone configuration?

Directions: Answer questions 3–10 in your group. Discuss answers to be sure everyone understands and agrees on the solutions. Round all answers to the nearest whole number, and label with the appropriate units.

The NBL pool is 12 meters deep and filled with water to help astronauts achieve a neutral buoyancy state when performing training activities. Answer the following questions to determine how much water is needed to fill the pool.

3. What is the volume of the NBL pool in cubic meters?

4. How many liters of water are necessary to fill the pool if 1 m^3 of water has a volume of 1,000 liters?

5. Suppose a pool had the same length and width of an NFL football field and a depth of 12 m. Would it require more or less water to fill the NFL football field-sized pool than to fill the NBL pool?

   - *Filling the NFL football field-sized pool will require more water.*
   - *Filling the NFL football field-sized pool will require less water.*

6. How many liters of water would be needed to fill the NFL football field-sized pool described in question 5?

7. How deep would the NFL football field-sized pool need to be to hold the same amount of water as the NBL pool? (Round to the nearest tenth.)

8. When the NBL pool was originally filled in 1977, it took 30 days to fill using a fire hose. Find the fill rate in terms of liters/hour.

9. A typical in-ground swimming pool holds 87,000 liters of water. Using the same fire hose, how long would it take to fill the swimming pool? (Round to the nearest tenth.)

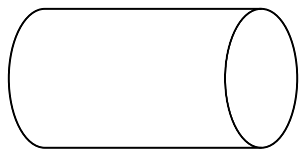
10. If a typical household hose was used, would it take the same amount of time, more time, or less time to fill the swimming pool?

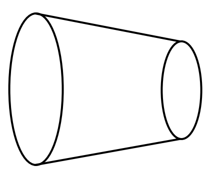
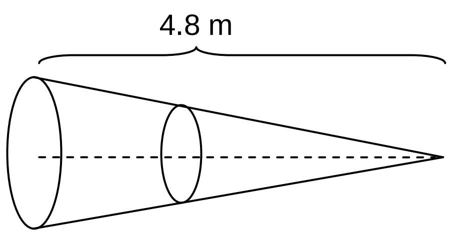
    - o *Same amount of time*
    - o *More time*
    - o *Less time*

Directions: Answer question 11 in your group. Discuss answers to be sure everyone understands and agrees on the solution, and then complete the table below.

11. One of the purposes of the NBL pool is to provide astronauts' training simulations for future spacewalks. The pool isn't just filled with water; it also contains various mockups of the ISS for this purpose. However, the actual amount of water in the NBL pool is less than has been calculated at this point. Why? (Hint: What happens when a person jumps into a swimming pool filled to the top with water?)

Directions: The dimensions of various mockups are given in the table below. Complete the table by calculating the space taken up by these mockups of various parts of the ISS. Round all answers to the nearest whole number, and label with the appropriate units.

<table>
<tr><th>Module Name
and “Basic” Shape</th><th>Dimensions
and “Basic” Shape</th><th>Volume of Module (m^3)</th></tr>
<tr><td>U.S. Laboratory Module (Destiny)</td><td>Height: 8.5 m
Width (Diameter): 4.3 m
</td><td></td></tr>
<tr><td>Pressurized Mating Adapters (PMA)

To calculate this volume, see the cone below: The PMA simply has part of the cone removed.</td><td>Height: 1.9 m
Width (Diameter):
1.9 m at wide end
1.4 m at narrow end
</td><td rowspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
</table>

Directions: Complete questions 12–13 independently. Round all answers to the nearest whole number, and label with the appropriate units.

12. Suppose the U.S. Laboratory Module (Destiny) is removed from the NBL pool. How many liters of water will be needed to fill the pool again? How long will it take using the fire hose? (Round to the nearest tenth.)

13. The NBL pool needs to be drained for maintenance. Suppose the drain hose removes water twice as fast as the fire hose fills the pool, and the Pressurized Mating Adapter and Destiny are the only mockups in the pool. How long will it take to drain the pool?